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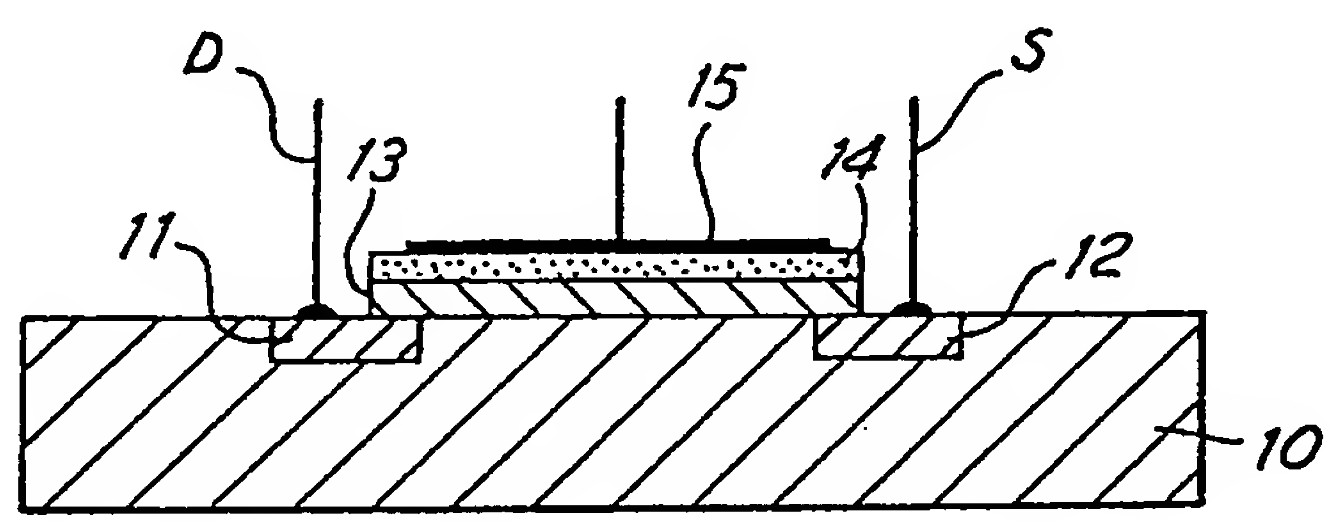
(54) Vapour sensor

(57) A vapour sensor comprises an insulated gate field effect transistor having a layer (14) of a vapour absorbent material between the gate electrode (15) and the gate insulator (13). The gate electrode is porous or patterned so as to allow vapour to be absorbed by said material (14) which, in response, undergoes a change of bulk dielectric constant. This causes a change in gate capacitance of the transistor resulting in a detectable change of electrical conductivity in the drain source channel. In the case of a sensor responsive to water vapour the layer (14) may be of a hydrophilic polymer e.g. a hydrogel. In the case of a sensor responsive to a basic or an acidic vapour the layer (14) may be respectively of an acidic or a basic polymer.



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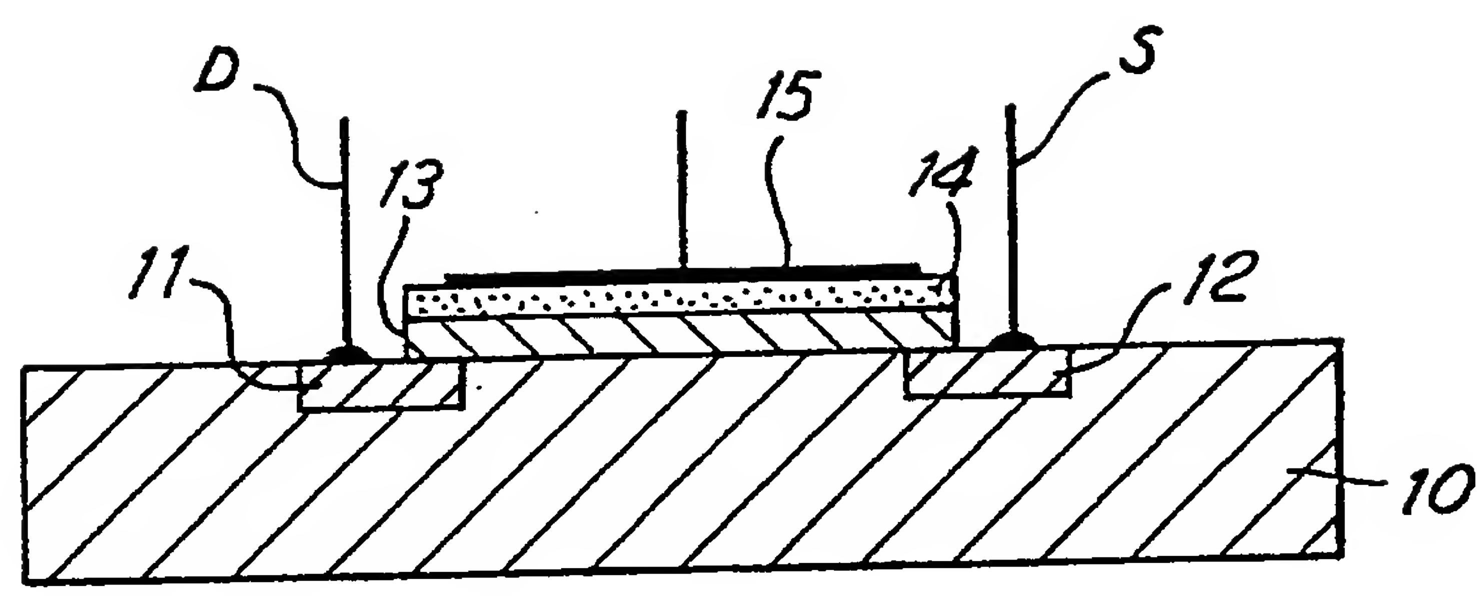

SPECIFICATION

Vapour sensor

This invention relates to a vapour sensor and it relates especially, although not exclusively, to a humidity sensor.

Vapour sensitive capacitors, especially humidity sensitive capacitors are known. These devices have the disadvantage that any change of capacitance brought about by a change of ambient vapour partial pressure tends to be rather small and so considerable care is needed to eliminate stray capacitance which could arise in an associated electrical circuit and would otherwise mask the effect to be detected.

It is an object of the present invention to provide a different form of vapour sensor.

According to the invention there is provided a vapour sensor comprising an insulated gate field effect transistor having, between the gate electrode and the gate insulator, a layer of a material capable of absorbing a selected one, or any one of a selected class of ambient vapour, said gate electrode being arranged so as to be capable of exposing said layer to the vapour, wherein said material undergoes, as a result of absorption, a change of bulk dielectrical constant thereby to cause a detectable change of electrical conductivity in the drain source channel of the transistor.

A change of bulk dielectric constant, caused by absorption of a vapour, results in a change of gate capacitance which for a fixed gate voltage, causes a corresponding change in drain current. The change in drain current depends of the amount of vapour absorbed which, in turn, depends on the vapour partial pressure and the affinity of the absorbent material for the vapour.

For a given sensor, therefore, the drain current can provide an indication of the vapour partial pressure.

An example of a vapour sensor is a humidity sensor in which the absorbent layer, between the gate electrode and the gate insulator, responds to ambient water vapour. It will be understood, however, that the present invention is intended to encompass sensors other than humidity sensor, the absorbent material being chosen to respond to a desired vapour or class of vapours.

In the case of a humidity sensor the absorbent layer, between the gate electrode insulator may be of a hydrophilic material, for example, a hydrophilic polymer. Such polymers may be in the form of a hydrogel, and we find that particularly useful hydrogels are formed from the polyacrylates.

Polyacrylate hydrogels can be formed by the polymerisation of a suitable hydroxyalkyl acrylate or methacrylate. The degree of hydrophilicity of the resultant polymer may be varied by co-polymerising the hydroxyalkyl methacrylate with, if enhanced hydrophilicity is required a highly hydrophilic monomer such as N-vinyl pyrrolidone or, if reduced hydrophilicity is required, a hydrophobic monomer such as styrene. An example of a suitable hydroxyalkyl methacrylate is hydroxyethyl methacrylate.

Examples of other hydrogels which can be used in a humidity sensor are cellulose acetate and cross-linked polymers of N-vinyl pyrrolidones and polyacrylamide.

In the case of a vapour sensor used to respond to hydrocarbon vapours, for example, benzene, the absorbent layer may be of a hydrophobic polymer, for example, cross-linked polystyrene.

In the case of a vapour sensor used to respond to a basic vapour, for example methylamine the absorbent layer may be of an acidic polymer, for example, cross-linked polymethacrylic acid.

In the case of a vapour sensor used to respond to an acidic vapour, for example, acetic acid, the absorbent layer may be of a basic polymer, for example, poly (diethylaminoethyl methacrylate).

An embodiment of the invention is now described, by way of example only, by reference to the only drawing which shows a cross-sectional view through the sensor.

The embodiment is described in relation to a humidity sensor. It will be understood, however, that the present invention is intended to encompass sensors which respond to vapours other than water vapour.

The humidity sensor comprises an insulated gate field effect transistor (IGFET) including between the gate insulator and the gate electrode a layer of a hydrophilic material. When this material absorbs water vapour it undergoes a change of bulk dielectric constant.

As is shown, if the drain voltage V_D is held at a fixed value, consistent with operation of the IGFET in the saturation region of the drain current-drain voltage (I_D-V_D) characteristic, the drain current I_D is related to the gate voltage V_G by the approximate expression

$$I_D = \frac{W}{2L}\mu C\,(V_G - V_T)^2$$

where W and L are respectively the width and length of the conduction channel and depend on the value of V_D, μ is the charge carrier mobility in the conduction channel, C is the gate capacitance, and V_T is the threshold voltage.

A change of bulk dielectric constant, caused by absorption of water vapour, causes a change in gate capacitance C which results in a change in the drain current. The extent of a capaitance change will depend on the amount of water vapour absorbed which is a function of the ambient water vapour partial pressure and the degree of hydrophilicity of the material forming the absorbent layer. When the IGFET operates at a fixed gate voltage at AC the drain current I_D can provide an indication of the ambient water vapour partial pressure.

Referring to the drawing, the sensor comprises a substrate 10 of a semiconductor material, typically

silicon. The substrate has a doping of one polarity type (usually p-type) and two spaced apart regions 11, 12 have a doping of the other polarity type (usually n-type). These regions constitute the drain and source and are provided with respective drain and source electrodes D, S. The gate insulator 13 is formed typically of a layer of silicon dioxide or silicon nitride or oxynitride and carries a layer 14 of a hydrophilic material. In this example, the material is a polyacrylate hydrogel, hydroxyethyl methacrylate. This material proves to be especially suitable since the degree of hydrophilicity can be controlled; if enhanced hydrophilicity is required the hydroxethyl methacrylate can be polymerised with a highly hydrophilic monomer such as N-vinyl pyrrolidone. Alternatively, if reduced hydrophilicity is required the hydroxethyl methacrylate can be co-polymerised with a hydrophobic monomer such as styrene.

Furthermore, a suitable catalyst for polymerisation is a photo initiator such as 2, 2'-azo-bis (2-methyl propionitrile) so that, if desired, the polymer can be patterned on the surface of the gate insulator by a photolithographic technique.

The gate electrode 15 comprises an evaporation of, for example, gold or copper on the uppermost surface of layer 14. To expose the absorbent material to ambient water vapour the electrode is patterned by evaporation through a suitably configured shadow mask or alternatively be etching the evaporation using, for example, an ion beam milling technique. Alternatively, if the electrode is made thin enough it will be sufficiently porous to provide the desired degree of exposure. To this end, the electrode should be typically between 100 Å and 500 Å thick, and preferably around 200 Å thick.

In operation of the sensor suitable gate and drain voltages V_G, V_D are applied at respective electrodes and the drain current I_D, indicative of ambient water vapour partial pressure, is monitored.

In the particular example of a humidity sensor it is desirable to operate the IGFET at AC (at frequencies of typically 1 kHz) thereby to offset any tendency for charge leakage in the absorbent layer.

It will be appreciated that the water absorbent layer 14 may be formed of polyacrylate hydrogels other than hydroxyethyl methacrylate, for example, hydrocypropyl methacrylate. Moreover, other forms of hydrogel could be used, for example, cellulose acetate and cross-linked polymers of N-vinyl pyrrolidone or polyacrylamide.

In the case of a sensor used to respond to vapours other than water vapour the absorbent layer 14 is of a material chosen to respond to a desired vapour or class of vapours. If the sensor is used to respond to hydrocarbon vapours - benzene, for example - the absorbent layer 14 can be of a hydrophobic polymer - cross-linked polystyrene, for example. If the sensor is used to respond to a basic vapour - methylamine, for example - the absorbent layer 14 can be of an acidic polymer - cross-linked polymethacrylic acid, for example.

If the sensor is used to respond to an aidic vapour - acetic acid, for example - the absorbent layer can be of basic polymer-poly (diethylaminoethyl methacrylate) for example.

Provided charged leakage does not occur within the absorbent layer sensors responsive to vapours other than water vapour may operate either at DC or AC.

CLAIMS

1. A vapour sensor comprising an insulated gate field effect transistor having between the gate electrode and the gate insulator, a layer of a material capable of absorbing a selected one, or any one of a selected class of ambient vapour, said gate electrode being arranged so as to be capable of exposing said layer to the vapour, wherein said material undergoes, as a result of absorption, a change of bulk dielectric constant thereby to cause a detectable change of electrical conductivity in the drain source channel of the transistor.

2. A sensor according to Claim 1 wherein said layer is of a hydrophilic material.

3. A sensor according to Claim 2 wherein said hydrophilic material is a hydrogel.

4. A sensor according to Claim 3 wherein said hydrogel is a polyacrylate.

5. A sensor according to Claim 3 wherein said hydrogel is cellulose acetate or a cross-linked polymer of N-vinyl pyrrolidone or polyacrylamide.

6. A sensor according to Claim 4 wherein said polyacrylate is formed by polymerisation of a hydroxyalkyl methacrylate with a hydrophilic monomer.

7. A sensor according to Claim 6 wherein said hydrophilic monomer is N-vinyl pyrrolidone.

8. A sensor according to Claim 4 wherein said polyacrylate is formed by polymerisation of a hydroxyalkyl methacrylate with a hydrophobic monomer.

9. A sensor according to Claim 8 wherein said hydrophobic monomer is styrene.

10. A sensor according to any one of Claims 6 to 9 wherein said hydroxyalkyl methacrylate is hydroxyethyl methacrylate.

11. A sensor according to any one of Claims 6 to 9 wherein said hydroxyalkyl methacrylate is hydroxypropyl methacrylate.

12. A sensor according to Claim 1 wherein said layer is a hydrophobic polymer.

13. A sensor according to Claim 12 wherein said hydrophobic polymer is cross-linked polystyrene.

14. A sensor according to Claim 1 wherein said layer is of an acidic polymer.

15. A sensor according to Claim 14 wherein said acidic polymer is cross-linked polymethacrylic acid.

16. A sensor according to Claim 1 wherein said layer is a basic polymer.

17. A sensor according to Claim 16 wherein said basic polymer is poly (diethylaminoethyl methacrylate).

18. A sensor substantially as hereinbefore described by reference to and illustrated in the accompanying drawing.

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